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Engineering Evaluation of M117 Bomb with Blunt Nose

by

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KEYWORD LIST

Listed below are keywords which serve as an index to the contents of this report (AFR 80-29).

Bombs, Conventional
Bombs, Blunt Nose
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Ricochet Devices
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M117
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FOREWORD

This test, Phase I of APGC Project No. 0157W, was conducted under the authority of Operational Support Requirement 240, dated 2 September 1953, and a letter from Detachment 4, Aeronautical Systems Division,* dated 26 June 1963, subject: "Request for Test." Active testing under Phase I began on 1 October 1963 and was completed on 19 June 1964. This report covers the tests that were conducted under Phase I. Phase II will consist of a contractor support test on another blunt nose design, and the results obtained under this phase will be published in a later report.

The following personnel were responsible for the planning and accomplishment of this project and/or the preparation of this report:

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ABSTRACT

Two attachments to the nose of an M117 bomb were tested in an attempt to determine if these devices would improve the bomb's ricochet and penetration characteristics. One of these attachments was a blunt nose shape; the other was a more complex shape that had been adapted from a model which an allied Air Force claimed to work successfully on their 400-kilogram bomb. Neither of these designs changed the ricochet characteristics of the M117 enough to warrant its adoption. However, several ideas are suggested for improved or different attachments to the M117 bomb, and it is recommended that these concepts be pursued further.

A series of tests was also conducted under this project to study the ricochet and penetration characteristics of the standard M117 and the BLU-14/B bombs. These tests were conducted to provide data for a comparison with the modified M117 bombs mentioned above. The results of these tests are presented in this report and substantiate the results that had been obtained during an earlier limited evaluation of the M117 bomb and the MLU-10/B mine.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

J. E. Roberts

J. E. ROBERTS
Major General, USAF
Commander

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ILLUSTRATIONS AND TABLES

SECTION 1 - INTRODUCTION

Due to the large number of M117 demolition bombs that are available in the Air Force inventory, several modifications to this bomb have been proposed to extend its usefulness. One of these was the blunt (sham) nose addition to the bomb which was designed to improve the ricochet and penetration characteristics of the M117. This modification was designed at the Air Proving Ground Center and manufactured in Air Force shops. The standard M117 bomb has very erratic ricochet patterns. Usually the bomb bounces too high and tumbles too much to be used as a skip bomb, and the critical angle of impact to insure penetration into the ground is too high for many uses. The BLU-14/B bomb, on the other hand, has a low, stable ricochet trajectory that is predictable within closer limits than that of an M117. In addition this bomb can be released from altitudes as low as 50 ft in straight and level flight without the danger of the ricocheting bomb hitting the aircraft. Moreover, the BLU-14/B will penetrate into the ground at an angle of impact that is less than half of that required by the M117 bomb. The performance and shape of the BLU-14/B low level penetration bomb served as the inspiration for the blunt nose idea. In addition, it was expected that the blunt nose would absorb much of the shock from an impact on a hard surface to reduce the chance of an immediate detonation of the bomb upon impact.

During the testing of the blunt nose configuration, another device to improve the ricochet and penetration characteristics of the M117 bomb was obtained. This device, called the anti-ricochet head, was developed by the Air Force of an allied country and was reported to be effective when used on their 400-kilogram bombs with the same overall shape as the M117. Subsequently, testing of this device was added to this project in order to determine the feasibility of its concept.

The objectives of this project were to determine the ability of the modified bomb to penetrate the ground at impact angles similar to those required for penetration of the BLU-14/B and to evaluate the skip-bomb effectiveness of the modified bomb in comparison with the standard M117 and BLU-14/B bombs. However, no tests were conducted to determine the critical angle of penetration of the M117 bomb with either group of the above additions. The most important function of these additions was to control the ricochet of the bomb. As none of the additions functioned properly in this role, they were not tested further.

Since one of the objectives of this project was to evaluate the skip-bomb effectiveness of the blunt nose M117 in comparison with that of the standard M117 and the BLU-14/B bomb, a series of tests was planned to expand the knowledge of the ricochet characteristics of these latter two bombs in order to provide more thorough data for this comparison. These tests were conducted as planned despite the failures of the blunt nose bomb and then expanded to collect as much data as could be efficiently used in an analysis of the ricochet and penetration characteristics of these two bombs. A limited evaluation of the M117 and the MLU-10/B mine had been previously conducted under APGC Project No. 0010W.* Since the MLU-10/B mine and the BLU-14/B bomb differ only in their respective fuzing, the ricochet and penetration studies of this report extended the scope of that comparison.

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* Refer to AIDR 63-31, Ricochet Characteristics of the M117 Demolition Bomb and the MLU-10/B Mine, August 1963, Confidential Report, Prepared by Deputy for Aerospace Systems Test, Air Proving Ground Center, Eglin AFB, Florida.

SECTION 2 - INSTRUMENTATION

Contraves phototheodolites and an aircraft tone release system were used during the aerial drops. Three phototheodolites tracked the aircraft to the point of test item release and then tracked the test item from release to impact. For those cases when the bomb ricocheted, it was followed from release to the final impact or to loss of track. The cessation of the aircraft's tone indicated the instant of bomb release and was recorded on an oscillograph. This record was correlated with the phototheodolite data to determine the time of release.

Standard survey methods and equipment were used to determine the slope of the terrain at the point of impact. Elevations were taken at two points a given distance away from the impact hole on each side of the crater along and perpendicular to the flight line. The four points per axis that were found by the survey were plotted on a graph, and the slope along each of these axes was then determined by fitting a curve through the four points.

SECTION 3 - DESCRIPTION, TEST PROCEDURES, AND RESULTS

TESTS OF THE M117 BOMB WITH A BLUNT NOSE

DESCRIPTION. The blunt nose M117 bomb consists of a standard M117 bomb with the blunt nose cap mounted on the front of the bomb (Fig. 1). A nut is used to secure the cap to the bomb. The weight of the blunt nose cap and nut is approximately 115 lb.

The blunt nose cap (Fig. 2) is fabricated from 1025 steel. A 1/4-in.-thick circular disk with a 3 3/4-in. concentric hole for the nut is welded onto a 3/8-in.-thick cylinder. This cylinder is approximately 15 1/4 in. long and has a 16-in. outside diameter. Eight braces, cut to fit the contour of the bomb's ogive and the inside of the nose cap are equally spaced inside the nose cap and welded to it (Fig. 3). Four self-locking, cup point, socket set screws are located 90° apart along the circumference of the cylinder and 2 in. from the open end of the nose cap. The set screws prevent the blunt nose from rotating due to the vibrations that are encountered while the bomb is being carried externally on an aircraft.

The 3/4-in.-thick hexagonal head section of the nut, which is machined out of 1035 steel, measures 6 in. across the flats. Two pieces of 7/32-in.-diameter Nylocks, 3/8 in. long, are inserted into the middle of the threaded section and about 180° apart to prevent the nut from unscrewing during flight.

The details of each component of the blunt nose are shown on Air Force drawing X63F11531, "Nose, Sham, for Bomb, M117, GP."

The holding power of the nut on the blunt nose was checked using a two-way torque wrench and the hexagonal head, closed-end, box wrench that had been specially fabricated to fit the nut. Since the latter is longer than the torque wrench, the torque available to tighten the nut with the box wrench is greater than that available to loosen the nut with the torque wrench. In fact, when the nut was tightened as much as one man could using just his own weight at the end of the box wrench, the maximum torque that could be steadily applied to the torque wrench (345 ft-lb) did not begin to unscrew the nut.

Due to the variations in the distance between the front surface of the bomb and the fuze well (the length of the available threaded section in the bomb), the nut occasionally would not hold the nose cap tightly on the bomb. Therefore, a one-quarter-inch shim was used during the test,

and the drawing was changed to reduce the smooth cylindrical section on the nut to 7/16 in.

FIT TEST. The blunt nose M117 was mounted on all appropriate stations of F-100 and F-105 aircraft to determine fit compatibility. Since the total weight of the bomb with the blunt nose is approximately 925 lb, it cannot be carried on the outboard stations of an F-100. Therefore, for the F-100 aircraft, it was only tested on a Type III pylon on the intermediate station and a Type I pylon on the inboard station. On the F-105 aircraft the blunt nose M117 was loaded on the 14-in. universal pylon, the multiple weapon pylon (MWP), and the centerline multiple ejection rack (MER). The ground clearance for an item hung on a wing station MER was determined by graphical methods.

The standard M117 was known to fit on all the above stations of both these aircraft; therefore, the only clearances that were checked were those that were affected by the addition of the blunt nose. Fit and clearances were physically checked with the aircraft in the normal taxi attitude, and one-quarter-scale drawings were used to determine the clearances to the blunt nose for those configurations that included deflated tires and compressed struts. A one-quarter-scale model of the M117 fitted with a blunt nose was used in conjunction with North American Aviation, Inc., drawing 22-963002 for the F-100 and Republic Aviation Corporation, drawings SK79-75245 and SK79-75246 for the F-105.

The following list shows the clearances that were determined:

F-100:	Clearance to the fuel plugs on the bottom of the inboard pylon using Mk 6 Mod 0 lugs (actual)	0 in.(fit with contact)
	Clearance to the ground at the intermediate station with the nose gear tire deflated and strut compressed with the main gear normal (graphical)	21 in.
F-105:	Ground clearance to the front center bomb on the centerline MER in the normal taxi attitude (actual)	7 3/4 in.
	Same as above (graphical)	8 1/2 in.
	Clearance between adjacent blunt noses on the MER (actual)	11/16 in.

Distance between the tail fin of one bomb and the nose of another bomb for bombs in tandem on an MER (actual)	8 1/2 in.
Ground clearance to the front center bomb on the centerline MER with all 3 tires flat and struts compressed (graphical)	3 1/2 in.

Mk 1 Mod 0 lugs were found to be not usable with any of the F-100 or F-105 pylons. These lugs were so short that the blunt nose attachment contacted the components on the bottom of the rack prior to engagement. The Mk 6 Mod 0 lugs gave a satisfactory fit on the F-105 pylons and the F-100 inboard pylon, although the lugs had to be backturned the maximum allowable two threads in order to prevent interference between the nose cap and the pylon structure on all pylons except for the MER. The fuel and air breakaway connections at the front bottom surface of the inboard F-100, Type I pylon had to be pushed as far up into the pylon as possible to prevent interference with the nose cap. This item cannot be suspended from the intermediate stations of the F-100 due to interference between the high-blow/low-blow switch and the blunt nose unless special long lugs are used. Moreover, it was difficult to suspend these items on the inboard stations of the F-100 and the two wing stations of the F-105 with either type pylon. The bomb had to be moved around until the rack would engage. The armament load crew usually required 5 to 10 minutes more to load this item than to load a normal M117 bomb.

Standard armament transportation and loading equipment and techniques were used to handle the blunt nose M117, with one exception. The obsolete M5 munitions trailer was used to transport the bombs between the ammunition preparation area and the aircraft loading area. Moreover, the two center bombs on the centerline MER of an F-105 aircraft, which must be hung after all four shoulder stations have been loaded, can only be loaded if the MJ-1 bomb loader is fitted with the 2000-lb capacity fork lift adapter. Without this adapter the bomb cannot be lowered far enough to clear the bombs mounted on the shoulder stations. In addition the innermost sets of sway braces on all four shoulder stations must be extended as far as possible and the outermost sway braces retracted as far as possible in order to allow sufficient space to manipulate the bombs onto the center stations. An attempt was made to load the center stations from the front or back of the rack, rather than from the side, without using the above adapter. This attempt was unsuccessful because of a lack of space.

FLIGHT COMPATIBILITY TESTS. Four blunt nose M117 bombs were carried

during one flight on the inboard and intermediate pylons of an F-100 aircraft to check the dynamic compatibility of this item with the F-100. Since no store ejection was planned for this mission, the high-blow/low-blow switches on the intermediate stations were set in the high-blow position. This action permitted the blunt nose bomb to be carried on the intermediate station without special lugs even though it meant a deviation from the armament loading checklist. The side drive assembly portions of an M190 fuze system were installed on three of the items to check for any possible arming wire withdrawal. The positions of the nut relative to the nose cap and of the nose cap relative to the bomb were marked so that it could be ascertained later whether any of these components had become loose or had rotated during the flight.

In accordance with the test plan, the pilot began the test at an altitude of 2500 ft and increased his speed from 400 KIAS to 600 KIAS in 25-KIAS intervals. At each of these intervals he subjected the test items to pulse maneuvers. These pulse maneuvers consisted of rudder kicks and snap motions of the control stick. At each 50-KIAS interval he tested the items' response to accelerations of +6g and -2g and a roll of 120 degrees per second in addition to the pulse maneuvers. After reaching 600 KIAS, the pilot maintained this speed in level orbiting flight for 5 minutes. Then he climbed to an altitude of 25,000 ft and passed through a speed of mach 1 in the subsequent descent.

No problems were encountered during the compatibility flight other than the anticipated flight degradation caused by the shape of the blunt nose. An inspection of each item after the flight showed that no rotation or loosening of either the nut or the nose cap had occurred. Moreover, there was no sign of any appreciable (more than 1/8 in.) arming wire withdrawal.

AERIAL RELEASE TESTS. A total of eight blunt noses were dropped during straight and level flight from an F-100 aircraft. These items impacted in sandy soil on a flat, cleared area, 300 ft wide by 1500 ft long, on Range 75 at the Air Proving Ground Center. This area was located in such a manner as to permit one Contraves phototheodolite to track a bomb to the ground and the other two to track to within 20 ft of the ground. A harp was used to assist the pilot in obtaining the correct altitude and release point during the dry runs. Since the aircraft's bomb tone release system, which was used to indicate the instant of bomb release, uses the air-to-ground communications frequency, the harp operator could not assist the pilot during the wet runs. Therefore, the pilot determined the bomb release point during the actual drops by means of his visual bomb sight and the information that he had received

from the harp operator during the dry runs. The Contraves phototheodolites tracked the aircraft up to release and the bomb from release to impact or to its final impact in the event of a ricochet. Spotting towers were used to locate the initial impact. The area around each impact crater was surveyed after the mission to determine the slope of the terrain parallel and perpendicular to the line of flight.

The phototheodolite and survey data were reduced to give the time and space-position information of the aircraft at release and of the bomb throughout its entire trajectory. The blunt nose failed structurally during impact on six of the releases. On the other two releases, the nose remained intact on the bomb. One of these bombs remained in the impact crater, and the other ricocheted. Data obtained from these drops are presented in Table 1. Data from two standard M117 bombs and from two BLU-14/B bombs are also included for comparison.

Fig. 4 is a picture of the blunt nose that was dropped on bomb No. 2. The blunt nose that was dropped on bomb No. 4 is similar in appearance. The blunt nose on bomb No. 3 broke in the same places, as well as in others, when it shattered. A close inspection of the blunt nose from bombs No. 2, 3, and 4 revealed that the failure occurred along the edge of the welds (see Fig. 4). A clearly visible interface between the original metal and the weld filler, instead of a continuum between the two, indicated that these welds were of very poor quality.

An attempt was made to increase the strength of the blunt nose to withstand the impact by reworking the weld along the perimeter of the disk, and by welding a 1/4-in.-thick by 1-in.-wide piece of metal onto the longitudinal seam of the cylindrical section (see Fig. 5). Two reinforced blunt noses were dropped on bombs No. 5 and 6. The results of these tests were similar to the earlier ones. The failures did not occur at the interface between the weld and the adjacent metal, but along a crooked line through portions of both the weld and the adjacent metal. The location of the rupture indicated that the stresses caused by the welding operation had weakened the metal sufficiently to cause it to break at that location first. Therefore, two more blunt noses were reinforced in the same way and then partially normalized in an attempt to remove the residual stresses caused by the welding operation. These items were heated to approximately 1100°F (the maximum temperature that was obtainable in the only oven at the Air Proving Ground Center big enough for these items) and then allowed to cool overnight in the oven.

Further examination of Fig. 4 and study of the blunt noses from bombs No. 5 and 6 showed that the bomb acted as a punch upon impact. The restraining force of the ground hindered the forward motion of the blunt

nose, but the inertia of the bomb caused it to punch through the center of the disk as it continued to move forward. The forward curvature (see Fig. 4) of what had been the center portion of the disk shows the result of this action. To prevent this type of damage, a 1 1/2-in.-thick torus with a 10-in. outside diameter was built of tool steel to fit on the front portion of the ogive of the bomb. It was annealed to relieve the stresses that were induced by the machining process. The torus was designed to distribute this punching force over a larger area of the blunt nose disk and was attached to the disk by six bolts (Fig. 5). This modified blunt nose had no noticeable affect on the ricochet characteristics of the M117 bomb that was dropped at 600 KIAS, but it did prevent the bomb that was dropped at 300 KIAS from ricocheting. The latter bomb tipped over on impact and skidded about 30 ft. This action is unusual because the impact angle was approximately 12 degrees. An M117 bomb normally ricochets at an angle less than 32 degrees. It was found pointing in a direction opposite to that from which it was released. A piece of the torus that had been used on the 600 KIAS drop was found. It had also failed as a result of the unretarded forward motion of the bomb itself (Fig. 6).

These last tests were both considered to have shown a failure of the blunt nose because the impact force (which varies approximately as the square of the speed) that caused a failure was only four times the force that did not and because of a mild soil condition. Therefore, additional strengthening, and hence additional weight, would be required to make this design operate properly.

It was felt that, even though the blunt nose concept may have merit, it would require extensive engineering to add the required strength and maintain a minimum total weight for the modified bomb. This effort would have been beyond the scope of this test project. Hence no more M117 bombs with blunt noses were tested.

TEST OF THE M117 BOMB WITH AN ANTI-RICOCHET HEAD

DESCRIPTION. The original anti-ricochet head included a thin aluminum nose cap to improve its aerodynamic features. Since it was felt that this cap would only shatter on impact and would not affect the ricochet characteristics of the system, it was not used on the two test models. Moreover, the dimensions of the anti-ricochet head were altered to fit the M117 bomb. In all other respects the design was the same as that used by the allied Air Force. The item consisted of three steel parts: the head, the plug, and the bolt (Fig. 7). In this case a tool steel was used because it was strong and available. The finished parts were annealed

at 1650°F for three hours, cooled in the furnace to 500°F, and then cooled to room temperature.

The plug screwed into the front fuze well of the bomb. The anti-ricochet head fitted over the plug and the front of the ogive, and contacted the bomb along two surfaces inside the head. These surfaces had been machined higher than the main interior surface of the head to insure at least two points of contact between the head and the bomb. The 1-in.-diameter bolt held the head in place on the bomb. This head consisted basically of two concentric rings approximately 8 in. apart and connected by a truncated cone. The front ring was about 8 in. in diameter and the rear one about 15 in. The entire head was one piece of metal, and its inside surface followed the contour of the bomb's ogive. The three pieces had a total weight of 80 lb.

Fig. 8 is a picture of the anti-ricochet head mounted on a M117 bomb suspended from the intermediate station of an F-100D aircraft.

FIT AND FLIGHT COMPATIBILITY TESTS. Since the anti-ricochet head is smaller in diameter than the blunt nose, a satisfactory fit on the F-100 aircraft was assumed and merely verified during the loading for the first aerial mission with this item. Fit compatibility was not checked on the F-105 aircraft. The flight compatibility was limited to determining whether this item could be safely carried and released at speeds up to 600 KIAS. No problems were encountered during straight and level flight and maneuvers to +2g at speeds up to 600 KIAS and at altitudes from 150 to 5000 ft.

AERIAL RELEASE TESTS. All three drops of the anti-ricochet heads (one was used twice) were at a nominal altitude of 150 ft and speed of 600 KIAS. Impacts were on the same test area used for the M117 blunt nose tests. The anti-ricochet head on the first item dropped failed at impact. The torque that was developed on the head by the impact forces sheared the 1-in.-diameter bolt at the interface between the head and the plug. The bolt was then increased to the full 3 1/2-in.-diameter size of the fuze well for a subsequent drop, and the plug was replaced by a suitably sized cylindrical spacer. This bolt also failed at impact. The forces that were generated during the impact twisted the anti-ricochet head off the bomb because the bottom of the head was restrained by its contact with the ground and the top was forced forward by the continued motion of the bomb. This action pulled the bolt out of the fuze well by stripping the threads.

The head from the preceding drop was thoroughly inspected and considered to be reusable. A bolt was then made for it which was similar

to that used on the preceding drop but lengthened by the addition of a straight cylindrical section, approximately 2 in. long. This lengthened portion fitted snugly into the fuze well and was designed to prevent the bolt from twisting out of the fuze well. The length of the bolt was determined by the size of the wax pad filler in front of the bomb. It was felt that the bolt should not extend into the bomb any farther than the wax pad in order that the bolt would not damage any explosive if the bolt ruptured the fuze well during impact. This head did stay on the bomb until the last of the four or five impacts of the ricochet trajectory, but it did not markedly alter the ricochet characteristics of the bomb. During this final mission, a standard M117 bomb was dropped simultaneously in a pair release with the M117 bomb with anti-ricochet head. The standard bomb ricocheted a total of about 6200 ft while the latter ricocheted only 5000 ft. More importantly the maximum height of the bomb with the anti-ricochet head during the first ricochet trajectory was 136 ft, as compared to the aircraft release height of 150 ft. The tail fin was torn off the anti-ricochet bomb at impact, and the bomb tumbled during its ricochet trajectory just as the standard bomb did.

RICOCHET AND PENETRATION CHARACTERISTICS OF THE M117, BLU-14/B, AND BLUNT NOSE M117 BOMBS

Tabulation of observed ricochet data for the M117, BLU-14/B, and modified M117 bombs are contained in Tables 2, 3, and 4. These data were obtained primarily from phototheodolite tracking of bombs from release through ricochet and show the release conditions, impact conditions, and data for the resulting ricochet trajectory.

Standard data reduction techniques and computer programs were used on the phototheodolite data to calculate both the aircraft's release conditions and the bomb's trajectory. However, the data for the beginning of the ricochet trajectory could not be reduced directly because of a loss of phototheodolite coverage due to the rapid, erratic change of direction of travel at impact and to the fact that sand is kicked up at impact and temporarily hides the bomb from the phototheodolites' view. This loss of data varied from 0.2 to 2.0 seconds in duration and made it necessary to extrapolate the position and velocity data of the initial portion of the ricochet trajectory.

The normal equation of motion for the trajectory of a bomb in air is a third degree equation. Such an equation was used to reduce the data from the first two bomb drops by fitting it to the known phototheodolite data points and extrapolating to the ground line. This technique proved to be unsatisfactory because: (1) the characteristic S-shaped portion of the third degree equation appeared in the extrapolated section of the

bomb trajectory, (2) the extrapolated impact point did not agree with the one that was determined from the phototheodolite data of the bomb's trajectory between release and impact, and (3) the extrapolated curve did not smoothly join the curve that was plotted from the known data points. Therefore, a second degree equation was used for the ricochet trajectory, and the trajectory was forced to go through the impact point as determined from the phototheodolite data between release and impact.

An attempt was made to correlate the manner of ricochet with terrain slope as measured in the vicinity of the bomb impact. As expected, wide variations in ricochet angles and velocities existed in data gathered during this test. However, this variation appeared to be little influenced by the terrain slopes as measured during this test.

Plots of ricochet velocity (as a percentage of the impact velocity) versus impact angle are shown in Fig. 9. The data points for the BLU-14/B and M117 group very well with similar data collected under a previous test (APGC Project No. 0010W). These data show that the maximum height and distance of the first ricochet of the M117 bomb are unpredictable and not dependent upon the release conditions. No determination can be made as to the exact parameters that do affect the ricochet characteristics. The ricocheting M117 bomb could possibly strike the delivery aircraft after a release below 150 ft above the ground level.* The ricochet data on the BLU-14/B bomb also do not show an exact predictability of the ricochet trajectory, but they do demonstrate that the ricocheting bomb does not endanger the delivery aircraft. Moreover, the ricocheting bombs do not tumble often, and when they do, the tumble is usually not severe. The data on the BLU-14/B and the M117 bombs verify the critical impact angles for penetration of about 12 degrees and slightly over 35 degrees, respectively, that had been determined during the above mentioned previous test.

The data points for the blunt nose M117 appear to form a group which lies between the BLU-14/B and M117 data, indicating that the blunt nose had an affect upon the ricochet characteristics of the M117.

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* This statement is based on the agreement between the data obtained during this project and APGC Project 0010W, as well as the results of the theoretical study that is reported in AIDR 63-50, Ricochet Behavior of Bomb, Demolition, 750-lb., M117 and Mine, MLU-14/B, September 1963, Confidential Report prepared by the Deputy for Aerospace Systems Test, Air Proving Ground Center, Eglin AFB, Florida.

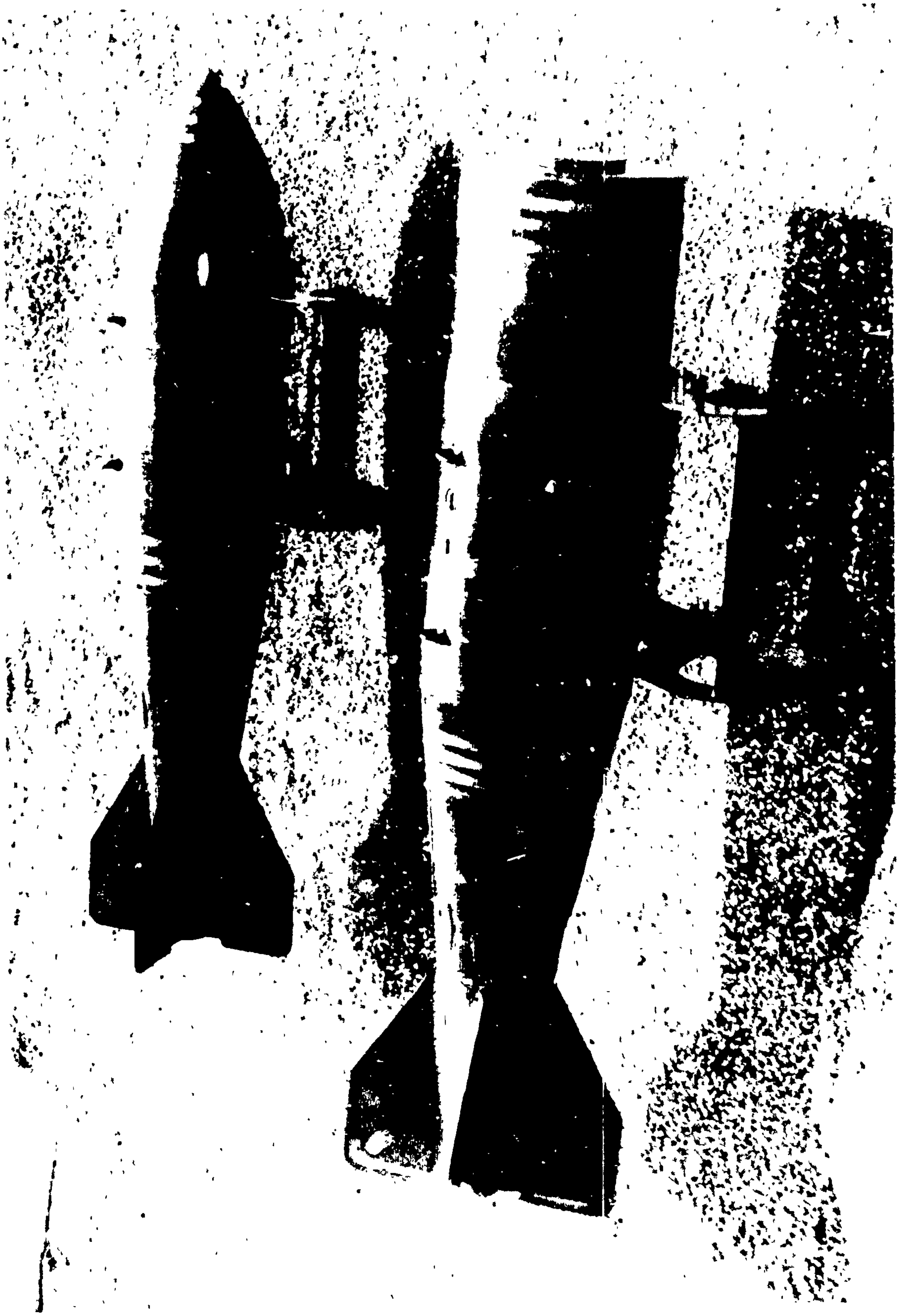

Fig. 1: Standard M117 Bomb and M117 Bomb with Blunt Nose Cap.

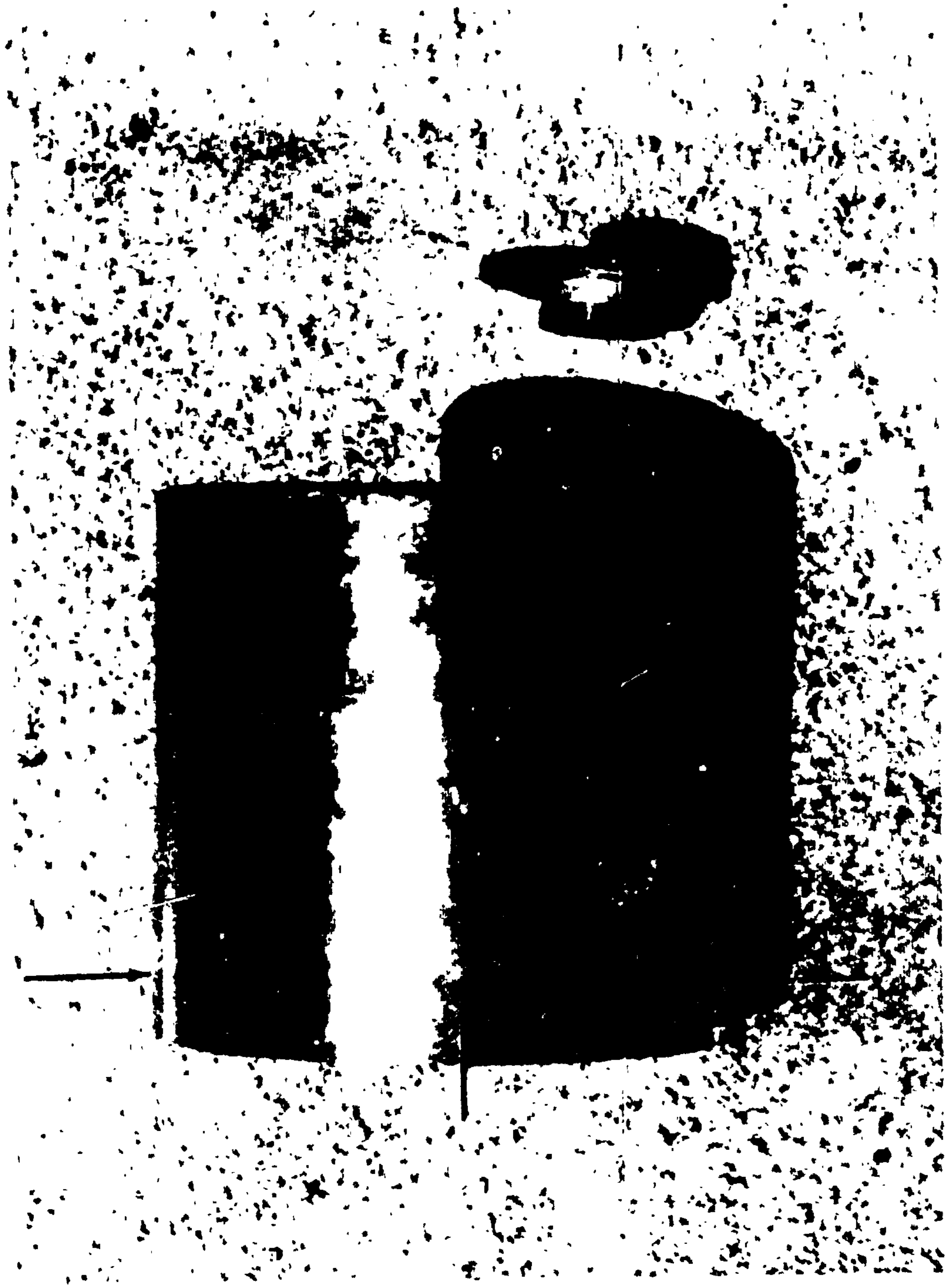

Fig. 2 Blunt Nose Cap and Nut. Arrows indicate location of three of the four set screws added later.

Fig. 3: Blunt Nose Cap Showing the Eight Braces.

Fig. 4: Blunt Nose Cap After a Drop. Arrows indicate areas where welds failed. Note forward curvature of center portion of the disk.

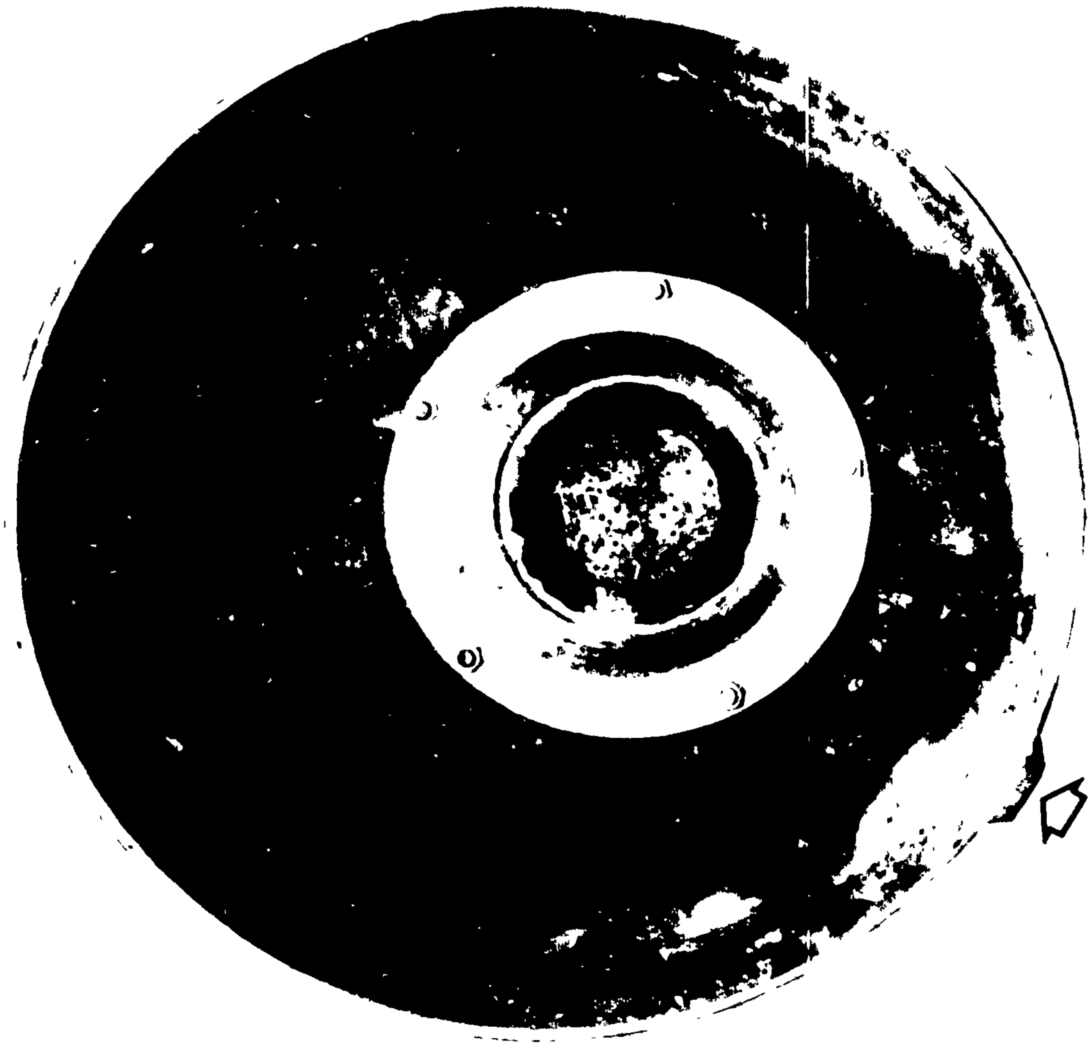

Fig. 5: Blunt Nose Cap Following Modification, Showing Torus Added to Distribute Punching Force of the Bomb and Reinforced Seam (arrow) of the Cylindrical Section.

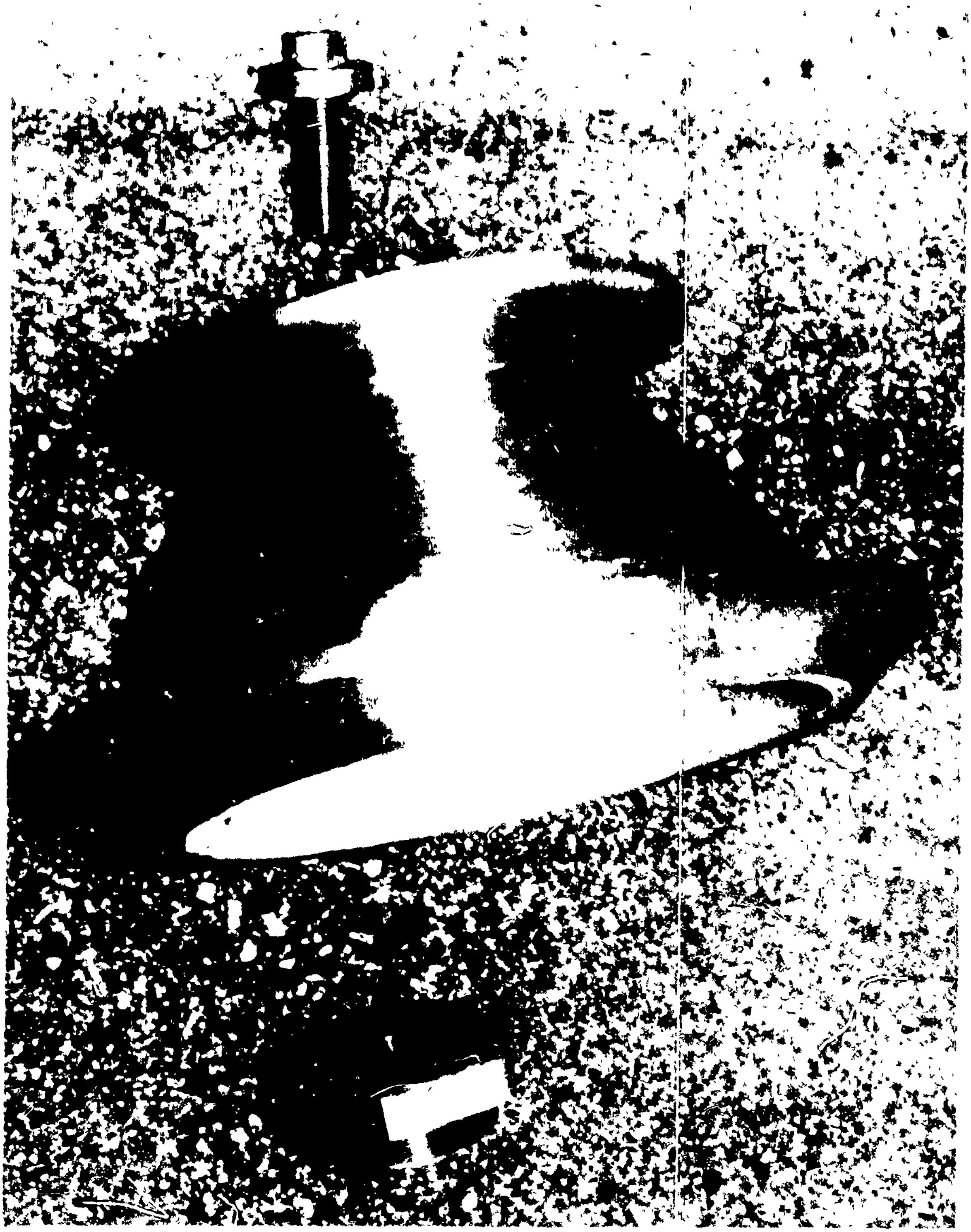

Fig. 7: Anti-Ricochet Head Assembly Showing (left to right) Plug, Head, and Nut.

Fig. 8: M117 Bomb with Anti-Ricochet Head Mounted on F-100D Aircraft.

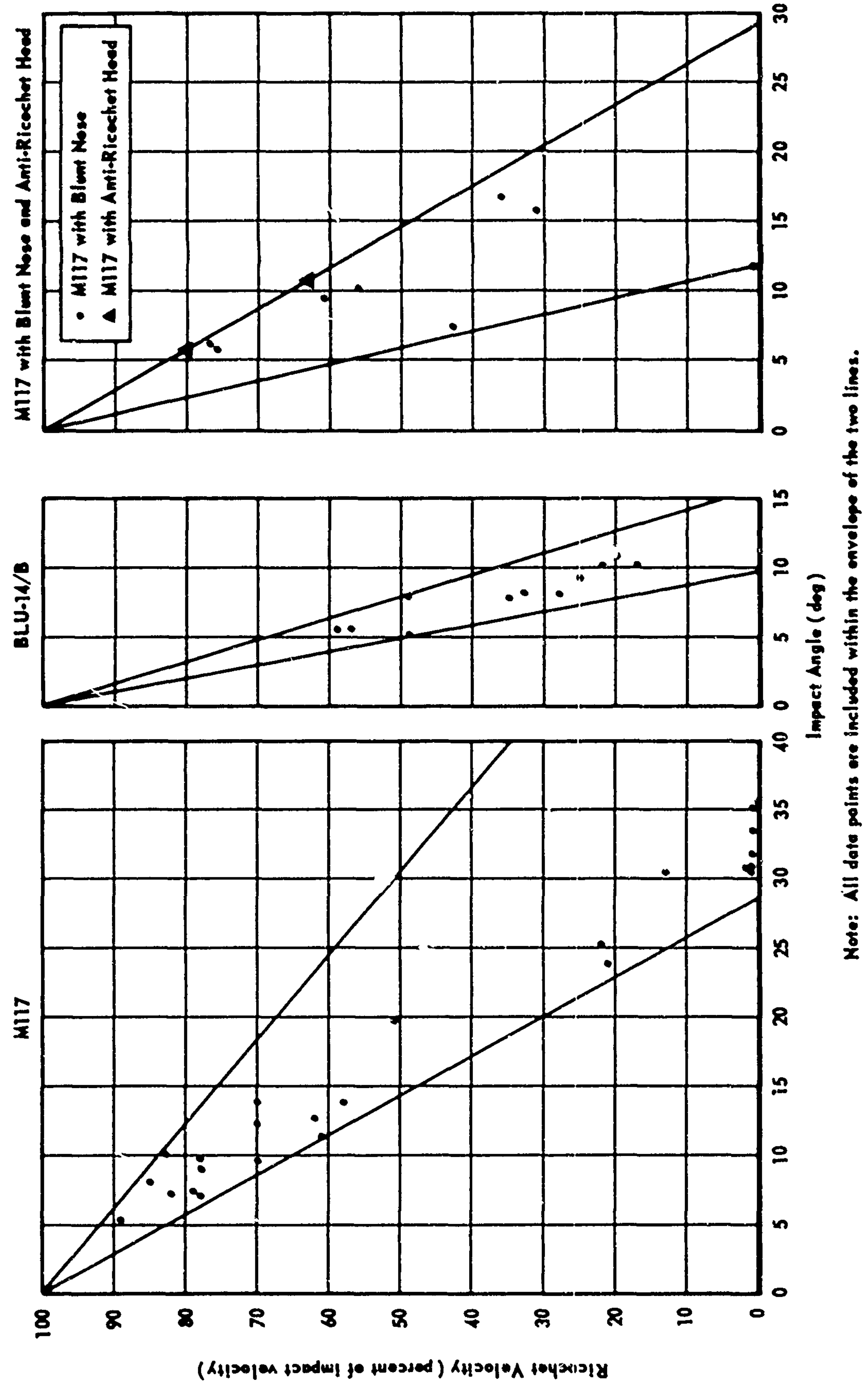

Fig. 9: Relative Ricochet Velocity Versus Impact Angle for Bombs Tested.

TABLE 1. RESULTS OF TESTS ON M117 BOMB WITH BLUNT NOSE.

Bomb No.	Release Conditions: Ground Speed (kt)	Release Conditions: Altitude (ft)	Maximum Height of First Ricochet (ft)	Total Ricochet Distance (ft)	Remarks
1	492	279	63	1750	Blunt nose stayed on bomb. Ricochet behavior approached that of BLU-14/B.
2	505	257	86	2250	Blunt nose came off bomb.
3	516	734	223	1700	Blunt nose shattered at impact and stayed in hole; the bomb ricocheted.
4	419	480	130	900	Blunt nose came off bomb.
5	608	148	375	5300	Welds on blunt nose reinforced, but the blunt nose came off bomb.
6	400	114	151	1200	Welds on blunt nose reinforced, but the blunt nose came off bomb.
7	584	154	200	6136	Welds reinforced and a torus added to front part of the blunt nose, but the blunt nose came off.
8	303	161	0	0	Same modification as No. 7. Bomb remained in impact crater with blunt nose intact.
9	396	190	276	4000	Standard M117
10	607	287	326	5800	Standard M117
11	405	191	0	0	BLU-14/B
12	626	258	61	950	BLU-14/B

TABLE 2: OBSERVED RICOCHET DATA FOR STANDARD M117 BOMBS.

Date	Release Conditions				Observed Impact Data				Observed Ricochet Data						
	Planned		Observed				Terrain Slope[1] (deg)					1st Ricochet Trajectory			
	Altitude Above Target (ft)	Airspeed (KIAS)	Altitude Above Target (ft)	Ground Speed (kt)	Impact Angle (deg)	Impact Velocity (fps)	Parallel to Line of Flight	Perpendicular to Line of Flight	Ricochet Angle (deg)	Ricochet Velocity (fps)	V_{Ric}/V_{Imp} [2]	Horizontal Travel (ft)	Maximum Height (ft)	Time (sec)	Total Ricochet Distance (ft)
13 Nov 63	150	525	280	509	9.0	843	+1	0	11.3	661	.78	3800	208	7.2	5000[3]
	150	400	300	420	11.3	709	+1	0	13.1	503	.71	3000	181	6.6	3000[3]
29 Nov 63	200	500	150	489	6.9	822	-1	0	13.4	640	.78	4350	292	8.7	3100[3]
	400	600	226	572	7.3	942	-1	0	9.3	740	.79	3950	193	6.5	4700[3]
	300	400	220	409	9.8	690	+1	+1	13.4	539	.78	3450	193	7.7	4200[3]
	400	500	182	504	7.2	840	+1	0	11.7	693	.82	3900	209	6.8	5200[3]
	400	400	234	417	10.3	700	+2	-3	5.4	585	.83	2050	53	3.8	5200[3]
19 Dec 63	200	500	92	485	5.3	807	0	0	7.1	715	.89	2800	133	4.2	2800[3]
	500	400	328	400	12.3	676	-1	0	12.6	472	.70	2800	160	6.2	2800[3]
20 Dec 63	300	600	287	607	8.0	973	+1	0	12.5	827	.85	5450	326	9.0	5800[3]
	200	400	190	396	9.5	664	-2	0	17.9	462	.70	3250	276	8.5	4000[3]
4 Feb 64	1500	300	1567	323	30.8	612	-1	0	Slight Ricochet						15
	1000	400	1020	438	19.7	755	+1	+1	21.7	382	.51	2700	187	8.4	2900[3]
	500	400	464	418	13.7	707	-4	-1	21.3	412	.58	3150	342	9.4	3280[3]
	1000	600	981	645	13.8	1015	+2	0	19.0	707	.70	7150	776	14.6	7900[3]
14 Feb 64	700	600	708	598	12.6	978	-4	+1	25.3	631	.62	6450	883	14.8	6450[3]
10 Mar 64	150	500	102	512	5.4	852	+1	0	No Data						6860[3]
12 Mar 64	150	500	98	495	5.1	828	+1	0	Do Data						6580[3]
2 Apr 64	2000	300	1851	321	33.5	620	+1	+3	Slight Ricochet						50
	2000	300	1958	309	35.1	609	0	0	Slight Ricochet						20
	1500	300	1388	309	30.5	593	+2	0	44.3	78	.13	198	43	3.3	200
	1500	300	1611	313	31.8	598	+1	-3	Slight Ricochet						
	800	300	850	299	25.2	543	0	0	37.6	122	.22	528	76	5.2	530
20 Apr 64	2000	300	2053	312	35.4	617	0	-1	Did Not Ricochet						
	1500	300	1510	322	30.5	608	-1	-2	Slight Ricochet						80
	1500	300	1490	313	30.8	595	0	-1	Slight Ricochet						50
	800	300	837	316	23.9	569	+1	0	33.0	121	.21	344	61	3.7	390
12 May 64	150	600	153	623	5.4	1010	0	0	No Data						8380[3]

[1] Positive angle parallel to line of flight indicates upward slope as seen by the pilot. Positive angle perpendicular to line of flight indicates upward slope to the pilot's right.
[2] V_{Ric}/V_{Imp} - Ratio of the ricochet velocity to the impact velocity.
[3] Tumbled.

TABLE 3: OBSERVED RICOCHET DATA FOR BLU-14/B BOMBS.

Date	Release Conditions				Observed Impact Data				Observed Ricochet Data						
	Planned		Observed				Terrain Slope[1] (deg)					1st Ricochet Trajectory			
	Altitude Above Target (ft)	Airspeed (KIAS)	Altitude Above Target (ft)	Ground Speed (kt)	Impact Angle (deg)	Impact Velocity (fps)	Parallel to Line of Flight	Perpendicular to Line of Flight	Ricochet Angle (deg)	Ricochet Velocity (fps)	V_{Ric}/V_{Imp} [2]	Horizontal Travel (ft)	Maximum Height (ft)	Time (sec)	Total Ricochet Distance (ft)
13 Nov 63	150	525	276	521	9.8	793	+2	0	Slight Ricochet						50
	150	525	276	521	9.5	799	+2	0	Slight Ricochet						250
18 Dec 63	150	400	130	396	8.3	640	+1	0	14.2	225	.35	900	42	3.2	900
	300	500	238	488	9.3	757	-1	0	13.1	189	.25	500	27	2.6	500
2 Jan 64	400	400	517	417	15.9	657	-1	0	Did Not Ricochet						
	400	500	486	508	13.0	754	+4	+3	Did Not Ricochet						
	300	400	302	392	13.0	627	0	0	Did Not Ricochet						
	400	600	525	616	11.4	871	0	-1	Did Not Ricochet						
3 Feb 64	300	450	266	473	9.9	734	0	+1	Did Not Ricochet						
	400	500	311	510	10.1	772	-1	+1	15.4	129	.17	270	19	2.2	490
	400	550	318	553	9.5	833	-4	-3	Did Not Ricochet						
	400	600	325	628	8.7	907	0	-1	13.4	300	.33	1180	72	4.1	2100
7 Feb 64	200	400	254	412	10.9	654	0	0	Slight Ricochet						45
	300	500	349	512	10.6	776	0	0	Did Not Ricochet						
	400	600	419	610	10.2	874	-1	-1	17.0	192	.22	652	52	3.7	950[3]
	150	600	339	620	9.0	902	-1	0	Did Not Ricochet						
11 Feb 64	200	400	191	405	9.6	648	0	0	Did Not Ricochet						
	300	500	250	504	9.1	784	-3	-4	Slight Ricochet						90
	400	600	472	622	10.9	858	0	0	Ricocheted in Series of Short Bounces						730
	150	600	258	626	7.7	922	-1	0	14.2	258	.28	950	61	3.9	950
12 Feb 64	500	400	501	403	15.9	635	-5	-2	Did Not Ricochet						
	200	500	193	496	8.0	777	+1	+1	9.8	379	.49	1355	59	3.8	1850
14 Feb 64	700	600	823	619	14.3	865	+2	0	Did Not Ricochet						
10 Mar 64	150	500	102	512	5.6	817	+1	0	5.5	466	.57	1027	24	2.2	2110[4]
	150	500	69	480	5.1	780	0	0	11.8	380	.49	1684	90	4.8	1850
11 Mar 64	150	500	98	495	5.5	792	0	0	10.0	465	.59	2231	100	5.0	2250

1 Positive angle parallel to line of flight indicates upward slope as seen by the pilot. Positive angle perpendicular to line of flight indicates upward slope to the pilot's right.

2 V_{Ric}/V_{Imp} - Ratio of the ricochet velocity to the impact velocity.

3 Tumbled in the horizontal plane with a period of 1.9 sec and slightly in the vertical plane.

4 Tumbled close to the ground. No period established.

TABLE 4: OBSERVED RICOCHET DATA FOR M117 BOMB WITH BLUNT NOSE AND ANTI-RICOCHET HEAD.

	Release Conditions				Observed Impact Data					Observed Ricochet Data						
	Planned		Observed				Terrain Slope[1] (deg)						1st Ricochet Trajectory			
Date	Altitude Above Target (ft)	Airspeed (KIAS)	Altitude Above Target (ft)	Ground Speed (kt)	Impact Angle (deg)	Impact Velocity (fps)	Parallel to Line of Flight	Perpendicular to Line of Flight	Modification Survived Impact	Ricochet Angle (deg)	Ricochet Velocity (fps)	V_{Ric}/V_{Imp} [2]	Horizontal Travel (ft)	Maximum Height (ft)	Time (sec)	Total Ricochet Distance (ft)
13 Nov 63	150[3] 150[3]	525 525	279 257	492 505	10.1 9.5	720 742	+2 +2	0 0	Yes No	9.4 11.0	404 449	.56 .61	1510 1850	63 86	3.9 4.8	1750 2250[5]
15 Nov 63	300[3] 150[3]	500 400	734 480	516 419	16.9 15.8	719 621	-1 -1	-1 -1	No No	31.1 30.3	247 190	.36 .31	1500 900	222 140	7.5 5.9	1500 900
30 Dec 63	150[3] 150[3]	400 600	148 114	608 400	5.8 7.5	889 631	+3 +5	0 -2	No No	15.7 20.2	672 273	.76 .43	5300 1200	375 151	10.0 6.2	5300[5] 1200[5]
11 Mar 64	150[3] 150[3]	600 300	154 161	584 303	6.2 11.7	865 489	0 -1	0 -1	No Yes	9.7 Slight	670 Ricochet	.77	4070	199	7.4	6140[5]
3 Apr 64	150[4]	600	-			No Data			No							
20 Apr 64	150[4]	600	509	609	10.7	943	+2	0	No	12.2	591	.63	3800	210	7.7	4220[5]
12 May 64	150[4]	600	153	623	5.6	983	-1	0	Yes	7.4	788	.80	3980	136	6.1	5010[5]

1 Positive angle parallel to line of flight indicates upward slope as seen by the pilot. Positive angle perpendicular to line of flight indicates upward slope to the pilot's right.

2 V_{Ric}/V_{Imp} - Ratio of the ricochet velocity to the impact velocity.

3 Blunt nose.

4 Anti-ricochet head.

5 Tumbled.

SECTION 4 - DISCUSSION

RESULTS

The tests of the blunt nose M117 seem to indicate that the blunt nose concept is not feasible in its present design. The present configuration is not strong enough to withstand impacts from low level releases of about 600 KIAS on sand. Any additional strength that could be added to the existing blunt nose would require either a change to special, expensive, somewhat scarce metals or a significant increase in weight. An example of how much metal is required in the nose section of a bomb to withstand such large impacts can be noted from the BLU-14/B bomb. The MLU-10/B mine case that is used as the body of this bomb has a flat front end, from which the design of the blunt nose for the M117 was originated. This front piece on the mine case is 2 1/2 in. thick. A disk that is only 1 in. thick and has the same diameter as the M117 bomb would weigh approximately 60 lb, and this weight does not consider the rest of the blunt nose structure. Therefore, an attachment for the M117 that would simulate the front section of the MLU-10/B mine case would probably weigh 200 lb. These estimates are best visualized if it is recalled that the frontal area of the M117 bomb at its widest point is approximately twice that of the MLU-10/B mine case.

Two other factors should be considered in addition to the above weight problem. The tests of the anti-ricochet head showed that the bolt that held the head in place became the weak link when the head itself was made strong enough to withstand the impact. Therefore, if a blunt nose shape were built in the disk and reinforced cylinder design, the same problem can be anticipated. When the disk and cylinder are increased in strength so that they are able to withstand the impact, the nut will no longer be capable of holding them.

The direction reversal of the blunt nose M117 bomb No. 8 (refer to page 9) indicates that this configuration might never function as a skip-bomb. The dynamic reaction of the bomb during impact depends upon the torque from the weight vector that is developed about the instantaneous point of application during the impact process. The length-to-diameter ratio of the bomb is not large (approximately one half that of the BLU-14/B bomb), and the M117 bomb impacts at a shallow angle during a skip-bomb maneuver. The torque developed about the center of pressure of the soil, which is on the front surface of the blunt nose bomb, by the axial components of the weight vector and inertial force is larger than that developed by the normal components of the weight vector. Hence the bomb tumbles counterclockwise when viewed from the left side with reference

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to the direction of travel. This tumbling action precludes the use of the blunt nose bomb as a skip-bomb.

The standard M117 bomb also cannot be used as a skip-bomb. In this case the restraining force of the soil acts along the ogive of the bomb, further away from the bomb's centerline and with a diminished component along the axial direction. Therefore, the bomb rotates in a clockwise direction when observed from the left. This action causes the tail fin to break as it hits the ground and removes all the stability from the bomb.

The tests that were conducted on the anti-ricochet head show that the relatively small (8-in. diameter) front flat surface is not large enough to effectively control the ricochet of the M117 even though the 15-in.-diameter ring is just 8 in. behind it. Apparently this shape is too similar to the ogive shape to sufficiently effect the geometry of the dynamics at impact. These tests also demonstrate the difficulty of retaining such a nose attachment on the bomb. The anti-ricochet head itself remained intact during all three drops, but the bolt that held the head on the bomb failed on the first two drops. This bolt did not pull out of the fuze well until the last of several impacts on the third drop and as a result can be considered to have performed satisfactorily. If a more effective ricochet controlling device is used, the forces that are developed at impact will put an even more severe stress on this bolt; consequently, the bolt might then fail on the first impact.

PROPOSALS

The following is a list of some ideas that might satisfactorily control the ricochet of an M117 bomb. A few restrictions must be kept in mind when considering any ideas for an attachment to the M117 bomb to control its ricochet. Such an attachment must be a "field fix", that is, it can be easily attached to a fully loaded high-explosive bomb by any munitions crew. The weight of the addition must be such that the charge-to-weight ratio of the complete round does not become too low. The minimum allowable charge-to-weight ratio is a judgement based on tactical requirements. And finally, the materials that are used must not be strategically critical or too expensive. The following proposals should only be considered after a thorough analysis has been conducted on the forces that are developed on various shapes during impact in different soils.

1. Strengthen the front disk portion of the blunt nose considerably and use a longer bolt. The cylindrical section and the eight ribs

might not be supporting the disk enough to warrant the weight that they add to the system. If this is true, they could be deleted from the design and replaced for aerodynamic purposes by an aluminum cylindrical section.

2. Use a greatly strengthened cylindrical section with a thin aluminum disk on the front for aerodynamic purposes. This concept might not work even if the structure withstood the impact. Such a drag device could possibly only slow down the bomb and reduce the length of the ricochet without giving the desired low, smooth, predictable ricochet that is characteristic of the BLU-14/B. However, if the basic idea proved to be satisfactory, then it could be improved by perforating the cylindrical section. This would decrease the pressure of the soil on the inside of the cylindrical section and thereby permit a reduction of the weight of the unit.

3. Use a frustrum of a hollow cone with the larger diameter section forward and the smaller diameter section contacting the ogive surface of the bomb. This hollow frustrum could be used either as a drag device similar to the above cylindrical section or to reinforce a strong front disk as in the first suggestion.

4. Attempt to find a lighter metal that is sufficiently strong to withstand the impact forces, but not strategically or economically unfeasible.

5. Fill the insides of a configuration that is similar to the present blunt nose with a plastic-type filler. In addition to increasing the strength of this system with very little extra weight, the filler would act as an energy absorbent during impact and tend to restrain the sideways or rotational motion of the blunt nose relative to the bomb.

6. Consider the possibilities of forcing the bomb to impact in a horizontal attitude. It is likely that analysis might reveal that the bomb would ricochet as desired if it were to impact with its axis parallel to the ground. A gyroscope, a change of the center of gravity, a variable center of gravity (controlled by a gyroscope or a mechanism that responds to inertial effects, vertical velocity, or time), control surfaces mounted near the nose of the bomb, or a retro-rocket mounted near the nose of the bomb are possible methods of attempting to achieve a horizontal impact angle.

7. Add an impact control device near the rear end of the bomb to prevent the bomb from rotating enough at impact to tumble during the ricochet trajectory. The standard M117 bomb normally impacts on the ogive portion of the bomb and rotates about the point of impact with the rear end of the bomb moving downwards. As the tail hits the ground it

is torn off, and the bomb is left without anything to stabilize it or prevent it from continuing to tumble. A device such as a circular scoop mounted around the bomb near the aft end might catch that end of the bomb in the ground long enough to force the nose back down and cause the bomb to ricochet more nearly with a steady, nose forward attitude.

SECTION 5 - CONCLUSIONS

1. Neither the blunt noses nor the anti-ricochet heads that were tested on the M117 bomb controlled its ricochet satisfactorily. These additions did not change the ricochet characteristics of the bomb enough to warrant the adoption of either one in its present form.

2. Several additional modifications and different concepts that were suggested by these tests may prove feasible in further testing.

3. The blunt nose and anti-ricochet head modifications for the M117 bomb appear to have an influence on ricochet characteristics.

4. Ricochet velocities and angles for given release conditions are not influenced by minor variations in the slope of the terrain at the impact area.

SECTION 6 - RECOMMENDATION

APGC recommends that efforts to design and test a ricochet controlling field attachment for the M117 bomb be continued. These designs should be based on a thorough analysis of the forces that are involved during an impact as a function of the shape of the bomb with an attachment.

Detachment 4, RTD concurs in this recommendation. Continued effort for the design and fabrication of a ricochet controlling device is now in progress.

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